

# Coronal Line Emission from NLS1s

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## Abstract

We discuss the optical coronal line spectra observed for a sample of 19 Narrow Line Seyfert 1 galaxies. We find no correlation between the coronal line strength and the soft X-ray power-law index derived from *ROSAT PSPC* data. There is a trend for broader coronal lines to have larger equivalent widths. In addition, a strong trend is found between line width and velocity relative to the NLR. This trend is interpreted in terms of a decelerating outflow, originating close to the nucleus.

*Key words:* galaxies: active; quasars: general; quasars: emission lines; X-rays: galaxies

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## 1 Introduction

As a class Narrow Line Seyfert 1 galaxies (NLS1s) are defined in terms of their optical emission-line properties (1). In recent years, however, NLS1s have been studied mainly in relation to their X-ray emission, which displays some peculiar properties. In particular, the soft X-ray emission from NLS1s seems to be extreme in its shape and variability, possibly due to an extreme accretion rate (2). To study this emission directly is difficult due to Galactic absorption. However, an indirect probe is provided by the high-ionization coronal lines. These forbidden lines arise from species with high ionization potentials ( $> 100$  eV), and are thought due to photoionization by the hard AGN continuum.

As part of a programme to study their multi-wavelength properties, we obtained optical spectra of 19 NLS1s with the *IDS* mounted on the *INT* at La Palma. These objects were not chosen to have strong coronal line emission, but rather to represent the range in observed X-ray spectral indices as observed using the *ROSAT PSPC*. The optical data were reduced using STARLINK software.

## 2 X-ray Emission and Coronal Lines

For each NLS1, we measured the strength and redshift of the strongest optical coronal lines, including [Fe VII]  $\lambda 6087$ , [Fe X]  $\lambda 6374$  and [Fe XI]  $\lambda 7892$ . The Hydrogen and Helium permitted lines along with several lines emitted from the NLR, including [O III]  $\lambda\lambda 4959, 5007$ , were also quantified.

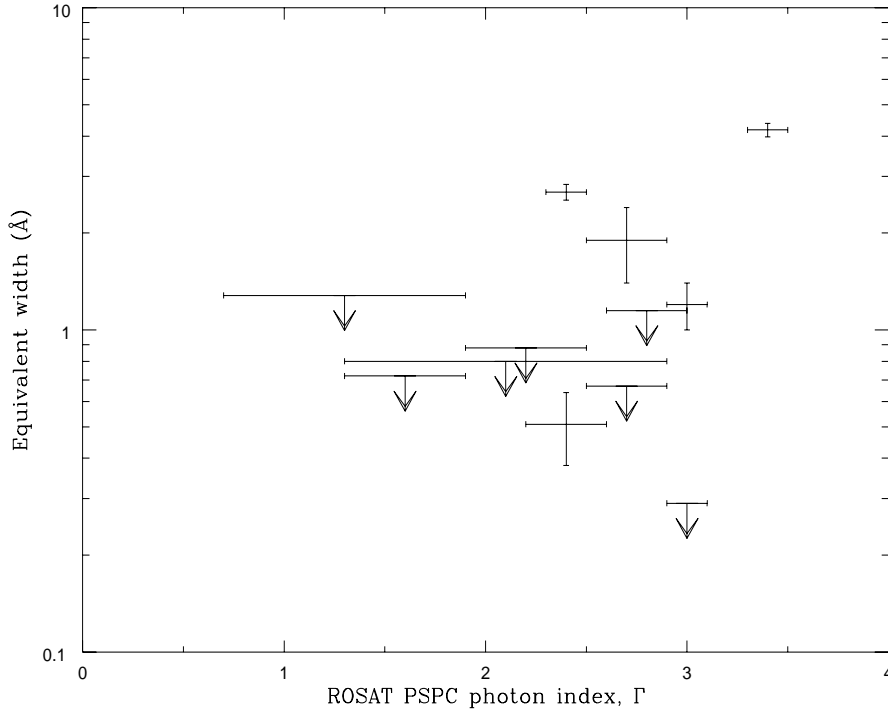


Fig. 1. The equivalent width of [Fe X]  $\lambda 6374$  versus the power-law photon index derived from *ROSAT PSPC* data.

In a previous study of AGN known to have coronal lines (3), it was found that the objects with the largest equivalent widths of coronal-line emission were those with the steepest soft X-ray spectra, based on power-law fits to the *ROSAT PSPC* data. In Figure 1 we show the equivalent width of [Fe X]  $\lambda 6374$  versus the photon index,  $\Gamma$  (taken from the literature). No correlation is seen and a wide range in coronal-line strength is observed for a given power-law index.

## 3 Kinematics

The exact location of the coronal line region is unknown, but it is believed to lie between the BLR and NLR, possibly associated with the dusty torus

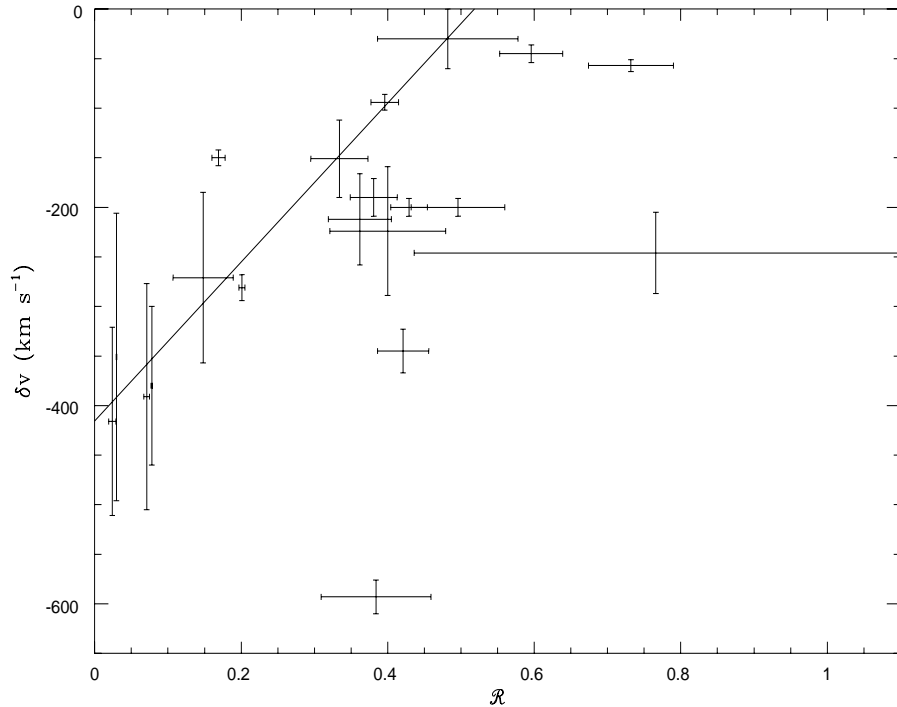


Fig. 2. The velocity of the Fe coronal lines relative to [O III]  $\lambda 5007$  versus the radial estimator (defined in the text). A best-fit line allowing for errors in both variables is also shown.

invoked in AGN unification models (4). As resolving the coronal-line region *via* direct imaging is difficult, to place some constraints we measured the FWHM and redshift of the coronal lines relative to the strong NLR line, [O III]  $\lambda 5007$ . Assuming the line widths are governed primarily by orbital motion, we define a ‘radial estimator’,  $R$ , such that

$$R = \frac{r_{[\text{Fe}]}}{r_{[\text{O III}]}} = \left( \frac{\text{FWHM}_{[\text{O III}]}}{\text{FWHM}_{[\text{Fe}]}} \right)^2,$$

where  $r_{[\text{Fe}]}$  and  $r_{[\text{O III}]}$  are the radial distances from the centre. In Figure 2 we plot the velocity of the coronal line (relative to [O III]  $\lambda 5007$ ) versus the radial estimator. A clear correlation is present such that broader coronal lines have larger blueshifts. The simplest interpretation is that the coronal-line gas is part of a decelerating outflow. The broader coronal lines also tend to have larger equivalent widths.

## 4 Conclusions

The lack of correlation between the coronal-line strengths and the *ROSAT* power-law indices is somewhat surprising given the predictions of photoionization models. It may be that the range in gas conditions or covering factors for the coronal-line regions between different NLS1s is quite large. The continuum shape may also be aspect-dependent, such that the steep soft X-ray continuum is not always seen by the coronal-line emitting gas. Finally, a single power law may provide a poor parameterization of the soft X-ray spectral shape. *ASCA* spectra of NLS1s do suggest a complicated spectral shape in some objects (5). The shape of the soft X-ray continuum in NLS1s will be accurately determined by forthcoming *Chandra* and *XMM-Newton* observations.

The kinematical results suggest a connection between the coronal-line emitting gas and the central region of NLS1s. In the context of a decelerating outflow model, the gas velocity is  $\approx 500 \text{ km s}^{-1}$  at a distance from the centre  $\approx 1/40$  that of the NLR. Given an NLR size  $\approx 100 \text{ pc}$ , this implies that the coronal-line gas originates at  $\approx 2 \text{ pc}$  from the centre. Such a small size could be associated with the outer region of the BLR and/or the inner edge of the proposed dusty torus.

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